

faces toward the wind. Turbulence and the more rapid movement of both trough and crest than of the middle of the "wave" dissipates the smoke in two or three minutes. In windy, cloudy weather the form of the smoke is essentially the same, for the waves produced in the wind by the unevenness of the ground have vertical movements somewhat like those of local heat convection, though usually on a smaller scale.

7. *Sea breeze or squall front.*—On the front of a sea breeze, the smoke blows inland from the top of the smoke-stack, but is carried up and returned seaward aloft. This has been observed from Blue Hill, Mass., on several occasions. There is the same bow formation on the front of a thunder squall, though the turbulence is so much greater that the bow is not so long.

From these observations of smoke, it seems that in so far as smoke movements make air currents visible, smoke becomes a valuable indicator of the structure of the wind.

THE STRUCTURE OF GUSTS.¹

By Major C. C. TURNER, R. A. F.

[Abstract.]

In a steady wind an airplane itself moves as if in a calm. Thus, if the wind is unsteady the number of gusts encountered in a given time will be the same whether there is a following or a head wind. And if, as anemometers indicate, gusts have no more abrupt onset than end, the effect of a gust from in front or of a lull from behind should be the same. Nevertheless, aviators say they can feel the difference between a head wind and a following one, and that they can climb fastest against the wind. Soaring birds apparently have the same experience. This would seem difficult to explain in any way other than that gusts begin more suddenly than they end. Apparently, we need more refined observations to show what the difference is.—C. F. B.

A VIRGINIA TORNADO.

By Prof. ALBERT W. GILES, University of Virginia.

[Dated: University, Va., Oct. 28, 1918.]

On October 29, 1917, a tornado occurred in the southern part of the State of Virginia that seems worthy of brief record. Gretna, a small village of some 200 inhabitants, situated in the north-central part of Pittsylvania County, 27 miles north of Danville, and on the main line of the Southern Railroad, was directly in the path of the disturbance and suffered severely. As a matter of fact, the destructive effects of the tornado were limited essentially to Gretna itself, its path being traceable but a short distance on either side of the town.

Tornadoes are very rare in Virginia. Greeley in his American Weather records less than five for the western part of the State between the years 1794 to 1881, and no published descriptions of this type of storm as occurring within the confines of the State are known to the writer.

In the study of the Gretna tornado no features new to tornadoes were discovered. It was simply a small storm of its class manifesting the usual phenomena. However, the date of its occurrence, very late in the autumn, is worthy of especial note as well as the lateness of the hour, 10:40 p. m.

Its path from the south-southwest toward the north-northeast may be traced continuously for a distance of about 2 miles, closely paralleling the Southern Railroad. In no place examined was the width of this path greater than 600 feet and locally it was but 150 feet wide. The accompanying map, figure 1, displays the direction of its course through Gretna.

The first evidences of destruction were found about one-fourth of a mile south of Gretna along the left side of the main highway. Here one or two trees had been twisted off and two straw stacks had been blown over. Passing beyond these the tornado crossed the main high-

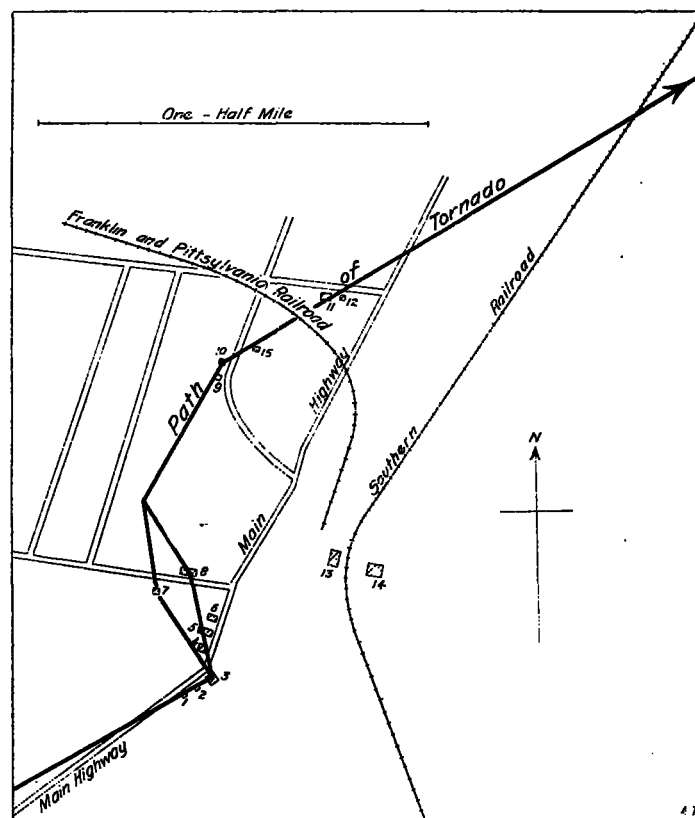


FIG. 1.—Sketch map of Gretna showing the path of the tornado through the village.

1. The Myers home.
2. The Eastman home.
3. Large tobacco warehouse destroyed.
4. Tobacco warehouse damaged.
5. Gretna Livery, Feed, and Sales stable.
6. Post office.
7. The Pickral home.
8. Powell's store.
9. The Eddie Bennett home.
10. The Dr. Powell's home.
11. The Christian Church.
12. The Adams home.
13. Southern Railroad station.
14. Virginia Hotel.
15. The J. E. Bennett home.

way and encountered the houses on the south side of the village. The first was a small frame structure (1, fig. 1) occupied by Mrs. Susie Myers. It was set back 3 or 4 feet and the back end rotated 8 feet from its normal position. Notwithstanding the unusual movements of her home Mrs. Myers preferred to remain in bed rather than to go out and face the storm. The next house (2, fig. 1), 100 feet north of the Myers home, was severely shaken but not damaged. The tornadic whirl apparently lifted over it only to descend with destructive violence on a large tobacco warehouse north-northwest 100 feet beyond. This building, 40 by 80 feet, substantially constructed of boards and three stories high, was totally destroyed (3, fig. 1).

¹ Aeron. Journ., London, 22: 285-6, 1918.



FIG. 2.—The ruins of the Gretna Livery, Feed, and Sales Stable. The tornado was traveling toward the northwest here and just missed the post office, the brick building in the background. Looking northeast. (E. H. Stevens, photo.)



FIG. 3.—Ruins of the Bennett home in the foreground, and the Powell home in the background. Looking northwest. (E. H. Stevens, photo.)



FIG. 6.—The rear of the Adams home. Looking northwest. (E. H. Stevens, photo.)



FIG. 4.—Front portion of the Bennett house, turned bottom upward and blown eastward, lodging against the shade tree at the street curbing. Looking west. (E. H. Stevens, photo.)



FIG. 5.—The remains of the Christian Church. The greater part of this structure was distributed along the pathway of the tornado for the distance of one-half mile to the northeast. Looking north. (E. H. Stevens, photo.)

Immediately after hitting the warehouse the tornado changed its direction to the northwest, and crossing the main highway again, split into two minor whirls, judging from the destructive effects. The whirl that took the right-hand course damaged a large tobacco warehouse (4, fig. 1), warping and twisting it, and then completely removed the top and upper story of the new brick structure occupied by the Gretna Livery, Feed & Sales Co. (5, fig. 1 and fig. 2). The almost complete destruction of this newly built and modern brick building affords an indication of the enormous forces resident within a tornadic whirl. A wagon body was carried 300 feet from this building, and hacks standing in a shed at the rear that was unroofed were turned upside down. From this brick building the tornado jumped a low shed, and striking the store of R. B. Powell (8, fig. 1), completely demolished it. One-eighth mile northwest of the Powell store the two whirls, which had followed nearly parallel courses, appear to have joined. The destructive effects of the left-hand whirl were limited, for its pathway lay largely through open country. However, it twisted the top off a well, unroofed a house, and picked up a small outbuilding, which it placed roof downward on the opposite side of a fence. A small two-story dwelling (7, fig. 1) standing 500 feet southwest of the Gretna livery stable was also demolished by this whirl, and its debris strewn for one-fourth of a mile northwest.

The reunion of the two whirls did not decrease the potency of the tornado, for the dwelling houses of Mr. Eddie Bennett and Dr. R. Powell (9 and 10, fig. 1, and fig. 3), standing directly in the pathway of the tornado, were practically leveled to the ground, including the brick foundations. There were six people sleeping in the Bennett home, all of whom escaped serious injury, almost miraculously it would seem. The front of the house was blown eastward into the street lodging against a shade tree (fig. 4), the back of the house was forced backward toward the west into the garden, and the top of the house was carried northeastward. The lower floor of the house was inverted. Apparently this house exploded, a rather common phenomenon in the case of buildings caught in tornadoes. Mr. Bennett was sleeping on the lower floor with his small son and was aroused to find that he and the bed had changed their respective positions. In the overturning of the floor the bed had been overturned on him. He was nearly half an hour in making his way out from beneath the wreck.

The Dr. Powell house was located adjacent to Mr. Bennett's on the north. The dining room and kitchen were displaced, the remainder of the house was completely wrecked. A baby 7 weeks old sleeping between the mother and father was instantly killed, having been struck on the head by a heavy object. The mother was seriously injured, and the father sustained slight bruises. The two other children were not hurt.

The metallic shingles of the Powell house, readily recognized by their green color, were driven into trees nearly 1 mile from the house to the northeast. Several were picked up at a distance of 9 miles to the northeast of Gretna, and later, observers reported having seen the shingles 30 miles northeast, in Campbell County. Heavy window weights were carried a distance of $1\frac{1}{2}$ miles from the house.

After the destruction of the two homes just described the tornado suddenly shifted its direction from north to northeast. In this direction it first encountered the home of Mr. J. E. Bennett (15, fig. 1) which was shifted backward from its foundation for a distance of 8 feet, leading the occupants to believe that the house had been

struck by lightning. Here two interesting occurrences illustrate the freakish features so often observed in the paths of tornadoes. A post firmly embedded in the hard ground to the depth of 2 feet or more was lifted clear of the surface without being damaged. A house cat was picked up and carried a mile, finally being deposited in a tree, where its lifeless body was seen hanging the next day, its nine lives having been insufficient to survive its experiences while in transit.

The Christian Church of Gretna (11, fig. 1), a large building substantially constructed of boards, was directly in the path of the tornado and was completely destroyed (fig. 5). The boards and heavy timbers were strewn for one-half a mile across the fields to the northeast. The heavy plank floor was lifted up and rotated through an angle of 15° with respect to the foundation. The heavy stoves were carried 800 feet, and pieces of the church organ were found three-fourths of a mile away.

The home of Mr. D. V. Adams (12, fig. 1 and fig. 6), a modern brick structure, suffered severely, the front of the house being removed almost entirely, together with the roof. Mr. Adams, with his wife and small child, had retired for the night, their sleeping room being in the rear of the house on the second floor. They were awakened by a terrific crash. Mr. Adams arose, thinking that the house had been struck by lightning. Upon discovery that it was raining very hard he went to the window to look out. His wife urged him to retire again, saying that there was nothing he could do, as the house had not been set on fire by the lightning. He noted a peculiar odor as if quantities of fine dust had been blown into the room, and a minute later he found that the ceiling of the room was leaking in one corner. Deciding to investigate further he stepped through the bedroom door into the front of the house to find himself standing in the open air.

The roof of the Adams house was carried for a distance of one-half a mile and dropped in a gully. A large portion of the family wardrobe was carried three-fourths of a mile northeast into the woods and left hanging upon the trees. Bed quilts were blown $1\frac{1}{2}$ miles to be carefully spread out without being torn. A brick from the house was blown through the thick board wall of the Methodist Church, 500 feet to the north-northeast, and displaced a pew some 3 or 4 feet from its original position. The Episcopal Church, 150 feet farther northeast, was moved slightly and the interior damaged. Fortunately it and the Methodist Church were east of the main path of the tornado, otherwise they would have experienced the same fate as the Christian Church.

From the Adams home the tornado passed northeastward across open fields to the north of Gretna, leaving a path strewn with every conceivable object—wreckage of buildings, household furniture, cooking utensils, clothing, etc. From these fields it entered a strip of woods three-fourths of a mile northeast of the village. Its track through the woods may be easily seen from a distance even with the dense foliage of summer on the trees. Nearly every tree in its path was felled, many being twisted off. The position of the tree trunks afford an excellent indication of the direction of the air currents in the tornadic whirl. Many of the trees on the right side of the path have fallen inward and slightly forward in the direction in which the tornado was moving. On the opposite side a number of trees have fallen inward also, but they tend to point backward in the direction from which the tornado came. This well illustrates the circular motion of the air currents in the tornado and their counter-clockwise direction.

Little destruction was effected beyond this strip of woods. Its path may be traced across the Southern Railroad near the Sulphur Spring, a mile northeast of Gretna, and into the woods on the opposite side of the tracks. It seems then to have lifted, dipping down here and there to the surface again. In one of these downward dips 8 or 10 miles northeast of Gretna a house was unroofed and a log blown across the bed of a man sleeping on the second floor. Not far distant a tobacco barn was likewise uncovered with the added interesting feature that the tobacco with which the barn was filled at the time was completely lifted out and carried onward. In one corn

had a section of its roof removed, and the Virginia Hotel (14, fig. 1), across the railroad from the station, had a small part of its roof torn up. The Masonic Temple was almost completely unroofed and the rear portion of the large warehouse of Shelton Bros. was removed. All of these buildings were east of the main path pursued by the tornado.

The noise of the tornado in its rapid passage through the village awoke a number of people. All accounts agree that it resembled most closely the roar of a fast limited train passing along the Southern Railroad at full speed. Scarcely a full minute elapsed from the time the roar of

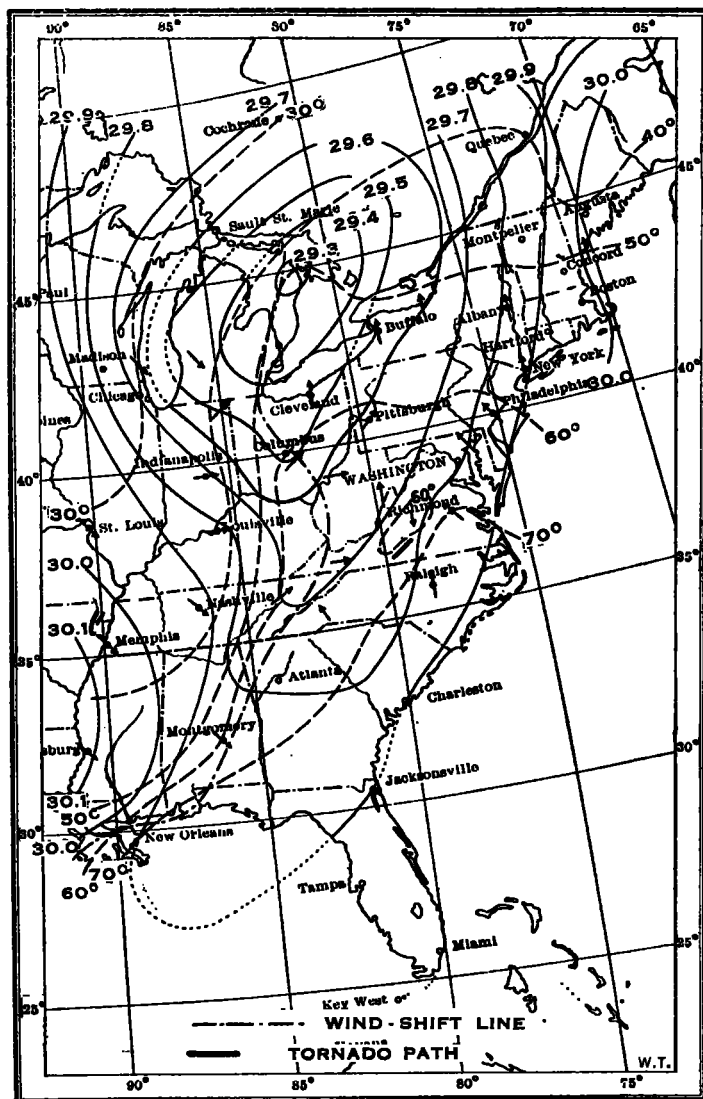


FIG. 7.—Weather map, 8 p. m. October 29, 1917.

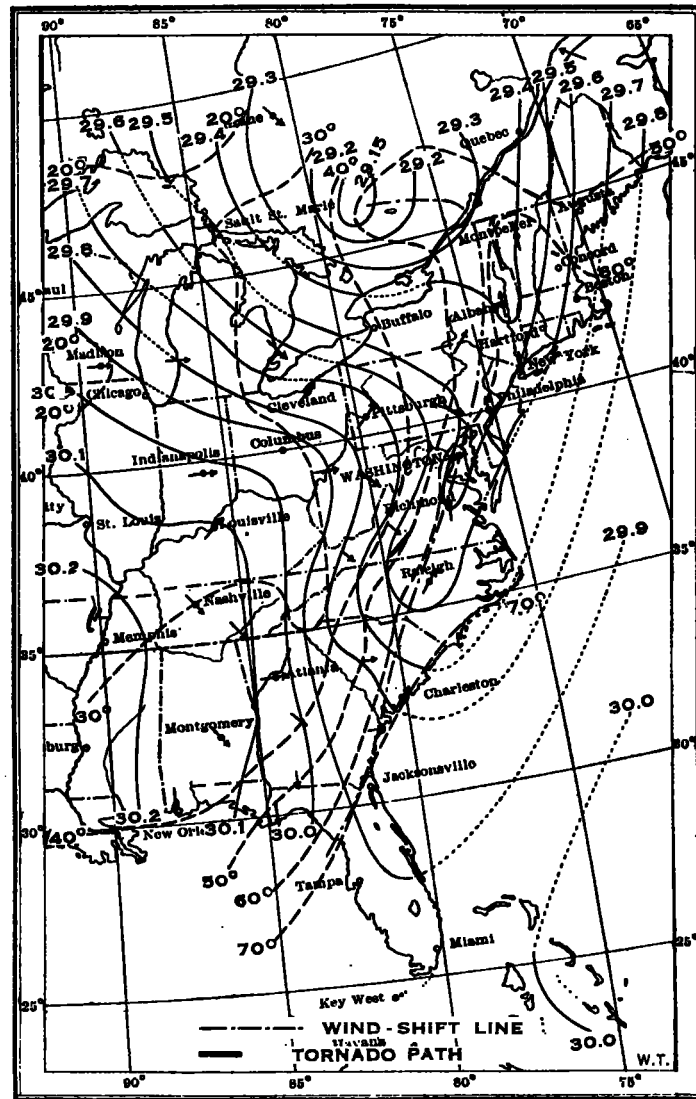


FIG. 8.—Weather map, 8 a. m. October 30, 1917.

field a number of ears were neatly husked and a quantity of stalks blown into the neighboring woods.

The noise of the passing tornado was heard at Gladys, a small town located 20 miles northeast of Gretna, frightening those people who had not retired. No damage was done, as the tornado was apparently several hundred feet above the earth's surface at the time. It was also reported east of Lynchburg where it was heard passing overhead shortly after 11 o'clock.

Buildings in Gretna not in the direct path of the tornado suffered slight damage from the strong lateral currents that accompany a tornado. The railroad station (13, fig. 1)

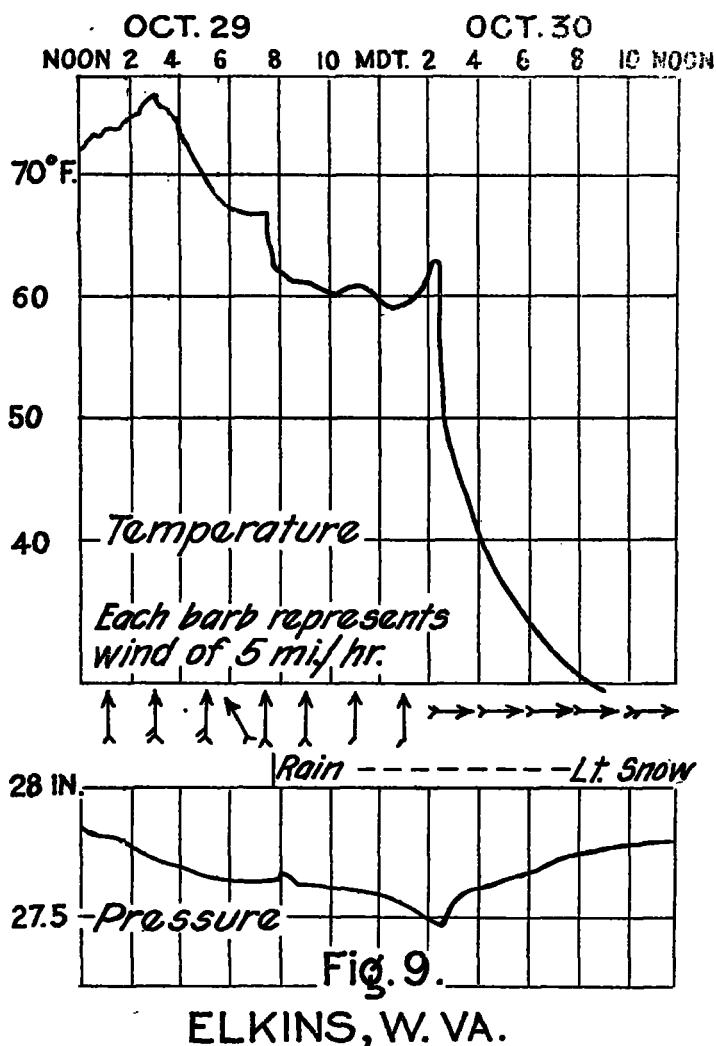
the tornado was first heard until it had died out in the distance. This would indicate a speed of 60 miles or more per hour.

The day had been unusual in some respects. It was bright and warm, excessively warm for the time of year. At 4 p. m. thundercaps began to form and by sundown it was quite cloudy with a close sultry atmosphere. A little later it cleared and a warm and gentle springlike wind began to blow. About 9 p. m. a severe windstorm was experienced which persisted for some time. At 10 o'clock the first thunder was heard, accompanied by sharp lightning; however, it did not begin to rain until just

before the time of the tornado, 10:40 p. m. The passage of the tornado was accompanied by a terrific downpour, the noise of which tended to deaden the roar of the tornado. This heavy rain continued for some time afterward and gradually slackening ceased altogether before midnight. The sky remained clouded for the rest of the night, the clouds hanging low and driving fast before a hard wind that followed the storm and persisted throughout the remainder of the night. After midnight it grew colder rapidly and the next day there was a light fall of snow.

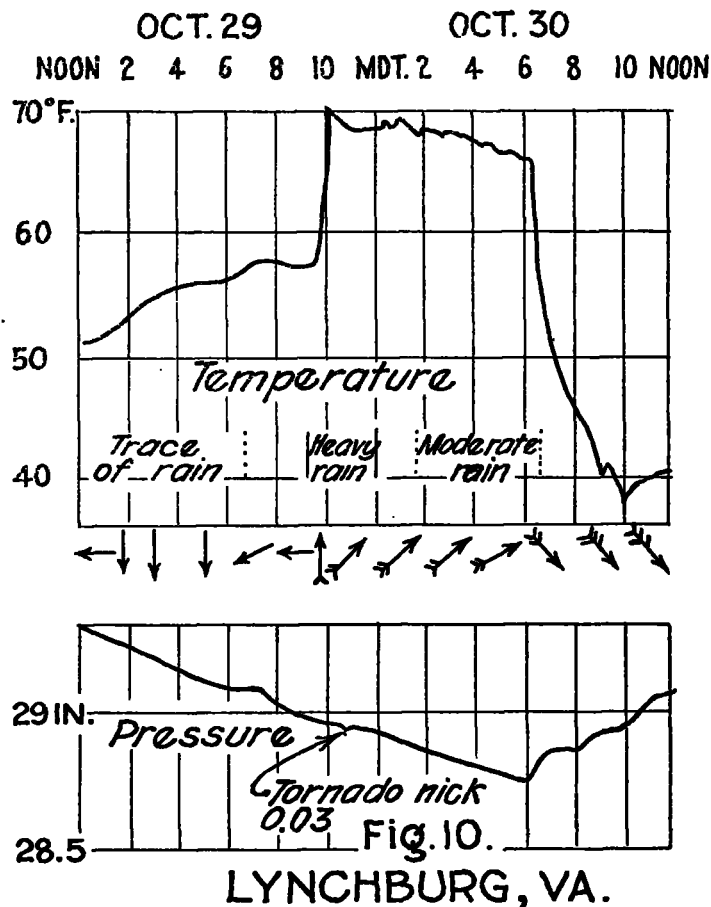
DISCUSSION.

Since this tornado was followed by a sharp fall in temperature at the passage of the wind-shift line of a marked V-shaped cyclone (see figs. 7 and 8) it would be natural on first thought to explain the storm as the result of cold air running over the mountains in advance of the wind-shift line at the earth's surface, and entrapping below it some of the warm, moist air on the Piedmont. This would cause intense local convection, and the result-



ing turbulence might be sufficient to produce a tornado. Such an explanation, however, does not seem to be justified by the facts. At Lynchburg, about 40 miles north-northeast of Gretna, there was no rise in pressure till 7 hours after the storm (see fig. 10), although some humps in the pressure curve might legitimately be expected if a considerable stratum of cold, dense air

arrived aloft. At Elkins, W. Va., rain began at 7:40 p. m., the temperature fell 6° F. at about 7:50 to 8:00 p. m., and there was a temporary, sharp rise in pressure amounting to 0.03 inch at about 8 p. m. (See fig. 9.) This is the only intimation that there may have been a cold wind front aloft which could have reached Gretna at the time (10:40) the tornado occurred.



Other conditions indicate that this tornado may be explained without assuming the arrival of a widespread cold wind running over the mountains. The stagnant cool air left from the anticyclone which was over this region the 28th was dissipated rather slowly; and at Lynchburg and probably westward to beyond the Blue Ridge some of this air remained till the evening of the 29th. (See fig. 7.) It is evident from the high temperatures and southerly winds at all surrounding stations, and from the cloudiness and light rainfall at Lynchburg during the day, that the warm, south wind was riding over this mass of cool air. Gretna seems to have been on the southern edge of the stagnant air until shortly after sunset, when "it cleared and a warm, gentle, spring-like wind began to blow." This light wind riding up over the cold air still at Lynchburg probably made the rainfall beginning there at 9:05 p. m.

At about 9 p. m. a severe windstorm of several hours duration began at Gretna; and 25 minutes later this wind reached the surface at Lynchburg, causing a remarkably rapid rise of temperature (see fig. 10).^{*} When the temperature had reached its maximum of 70° F. at Lynchburg the first thunder was heard at Gretna (10 p. m.), and 40 minutes later the tornado occurred there. Whence came the cold air necessary to produce such an

^{*} Cf. abstract on next page.